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ROYAL AIRCRAFT ESTABLISHMENT

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A COMPARISON OF LIQUID AND SOLID PROPELLANT BOOST ROCKET MOTORS

by

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Technical Note No. R.P.D.25

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ROYAL AIRCRAFT ESTABLISHMENT, FARNBOROUGH

A Comparison of Liquid and Solid
Propellant Boost Rocket Motors

by

L.W. Broughton
and
H.J Frauenberger

SUMMARY

Boost units for test vehicles and missiles have up to the present
used only solid propellants. Because of the need for boost units of
higher thrust and efficiency the possibility of the development of
liquid propellant boost units of total impulse 43,000 and 150,000 lb-sec
has been examined and their performance compared with that of the solid
propellant type.

The conclusion is reached that whilst liquid boost units could be
developed to give a better performance (based on total impulse per unit
weight) than solid boosts known at present, the development of solid
boosts giving as good, or better performance is equally promising; on
these grounds, therefore, there seems little justification for the
development of a liquid boost.

The liquid boost has the advantage, however, of greater flexibility
in installation in that the combustion chamber can be fitted at the
rear of the vehicle and thus ensures a purely axial thrust; at the same
time the tanks can be mounted at any suitable point around the body
of the vehicle so that the shift in the centre of gravity is reduced to
a minimum.

If, the supply of any future high performance solid propellant were
insufficient to meet the demand, the development and use of a liquid
boost motor might be justified on this account alone.

1. Liquid rocket propellant motors   I. Broughton, L.W,
                                       II Title
2. Booster rockets

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1   Introduction

To launch a rocket projectile or test vehicle a boost motor giving
a high initial thrust is generally required in order to bring the pro-
jectile to its working speed range in the minimum time. Up to the present
this field has been covered by solid propellant boost units because of
the greater amount of knowledge available and the simplicity of design
and handling as compared with liquid propellant motors.

With the higher launching accelerations and operating speeds now
required of projectiles and test vehicles a considerable improvement in
thrust and efficiency of solid boost units is required[1]. An improvement
in efficiency can only be obtained by an increase in specific impulse of
the propellant or by a reduction in structural weight, and although
developments of solid units along these lines are proceeding, it was
thought desirable to investigate whether it is possible to build a liquid
boost unit giving a better performance in terms of total impulse per unit
weight than the solid type.

The use of liquid propellants for boost units does not appear to
have received much attention so far although a number of different types
of liquid rocket motors have been successfully developed. Apart from
a few exceptions no short duration liquid rocket motors have been pro-
duced, one exception being the Taifun of $2\frac{1}{2}$ seconds duration[2]. This uses
self igniting propellants (nitric acid and W.A.F.I.) and gives a thrust
of 1700 lb which is too low in magnitude for a boost unit.

In the present note the possibility of developing liquid propellant
boost units of total impulse 43,000 and 150,000 lb-sec is investigated
and their performance is compared with that of existing and proposed
solid propellant boost units. The performance figures are necessarily
approximate as no detailed design work has been done on the liquid boost
units, but they are sufficiently accurate for assessing the relative
advantages of the two types of system.

2   General requirements for liquid boost

Two sizes of liquid boost unit are considered:-

(i)   total impulse 43,000 lb-sec.

(ii) total impulse 150,000 lb-sec.

The first is equivalent to the solid boost unit now in use on R.T.V.1
consisting of seven 5" L.A.P. rockets, fitted in tandem at the rear of
the test vehicle, whereas the second is comparable with the size of
boost that will probably be required for test vehicles the size of R.T.V.2.

The addition of the boost unit to the projectile should make the
smallest possible change in the shift of the centre of gravity; the
boost which is expendable is to be jettisoned after use. To make the
unit as safe as possible, non-self-igniting propellants (nitric acid and
kerosene) are considered.

The performance requirements are summarized as follows:-

	(i)	(ii)
Total impulse (lb-sec)	43,000	150,000
Duration (sec)	$3\frac{1}{2}$	$3\frac{1}{2}$
Thrust (lb)	12,300 ($5\frac{1}{2}$ tons)	43,000 (19.2 tons)

3   Description of liquid boost

A number of different boost schemes are considered, but they differ mainly in the shape and disposition of the propellant tanks. In all cases the boost combustion chamber is located immediately behind the main rocket chamber, which conveniently forms an ignitor system for the boost. The injector, which may be in the form of pre-mixing swirl nozzles, impinging jets or annular slits, may be fitted either around the periphery of the injector head or across the exit from the main chamber.

The main motor chamber is used as an ignitor on the assumption that sufficient heat will be available from the combustion gases to ignite the boost. With this method of ignition it is essential for the main rocket combustion chamber pressure to be 3 to 5 atm higher than that of the boost and hence there is necessarily a slight reduction in the specific impulse of the boost motor. During the operation of the boost the thrust of the main motor is low, but it will attain its maximum value upon the release of the boost. A pyrotechnic ignitor for the boost is also considered, as this will allow the combustion chamber pressure and, therefore, the specific impulse to be raised.

In all cases the weight of the supporting structure for the boost is taken as 10% of the total weight of the boost unit (including propellants).

Design details are given in Appendices I and II.

3.1   "Tandem" boost

A "tandem" arrangement (Scheme 1) is shown in Fig.1. Surrounding the boost combustion chamber are the propellant tanks, the nitric acid tank being to the rear. The propellants are fed through inner and outer chamber coolant jackets on their way to the injectors, although nitric acid itself would suffice to cool the chamber. A disadvantage of this tandem boost is the shift in the centre of gravity of the combined projectile and boost after the release of the boost since the mass of the boost unit is located at the rear; this shift is, however, less than that obtained with the existing solid boost of R.T.V.1.

3.2   "Wrap round" boosts

In these boosts the propellant tanks are "wrapped" around the body of the test vehicle, the propellant tanks in Schemes 2, 5, 6 and 7 (Fig.2) are in the form of tubes and in Schemes 3 and 4 (Fig.3) in the form of cylindrical and elliptical "rings" respectively. For Schemes 3 - 7 the dimensions of the tanks were determined on a minimum weight basis. The actual size and disposition of the tanks will be governed, of course, to a large extent by the position, number and movement of the aerodynamic fins and control surfaces of the projectile.

As in Scheme 1, one combustion chamber only is used which is fitted immediately behind the main motor, although in this case the chamber is uncooled. The injector arrangement remains the same.

4   Performance estimates of liquid boost

The designed maximum specific impulse is 198 sec which is 90% of the theoretical value of 220 sec. Because of the extremely short duration of the boost it is very important that there should be no wastage of propellants at the start and end of injection as this can cause quite a

serious reduction in the mean specific impulse. As there appears to be
little practical experience on this point it was decided to compare the
performance of the boost at two different mean specific impulses (a)
167 sec (allowing 19% propellant wastage) and (b) 185 sec (allowing 7%
propellant wastage). Although the value (a) is probably pessimistic,
it does represent a figure that should be fairly easily attained, whereas
the value (b) should be capable of attainment after further development.

4.1 Liquid boost of total impulse 43,000 lb.sec

Comparative weights for Schemes 1 - 6 at a mean specific impulse
of 167 sec are shown in Table I from which it will be seen that the scheme
giving the lowest weight is No.6 (4 × 5" steel tubes) with a total impulse/
boost weight ratio of 93. Raising the specific impulse to 185 sec for
Schemes 3 - 6 gives an increase in total impulse/boost weight ratio of
about 7% in all cases (Table II).

The use of the main rocket combustion chamber as an ignitor for the
boost motor limits the chamber pressure and, therefore, the efficiency
of the boost. If an independent ignitor system, such as a solid charge,
can be used for the boost motor, then much higher pressures can be used.
Raising the combustion chamber pressure from 16 to 30 atm increases the
mean specific impulse from 167 to 177 sec, (allowing 19% propellant
wastage). The resulting reduction in weight for Scheme 6 (Table III)
gives an increase in total impulse/boost weight ratio from 93 to 97 or
4%. This improvement in performance is almost entirely due to the
reduction in propellant consumption because of the higher specific
impulse, the dry weights in both cases being almost identical. If the
propellant wastage is reduced from 19% to 7% (giving a mean specific
impulse of 196 sec), then the total impulse/boost weight ratio at 30 atm
chamber pressure is increased about 7% and reaches a value of 104.

To sum up, therefore, Scheme 6 appears to offer the lightest form of
construction. If the conservative figure for mean specific impulse of
167 sec, and a chamber pressure of 16 atm is taken a total impulse/boost
weight ratio of about 93 should be attained. At the more optimistic
figures of 196 sec for the mean specific impulse and 30 atm for the
chamber pressure it should be possible to realize a total impulse/boost
weight ratio of about 104. Such liquid boost units would probably take
at least 2 years to develop.

4.2 Liquid boost of total impulse 150,000 lb-sec

For the boost of total impulse 150,000 lb-sec the only arrangement
considered was Scheme 7. The estimated weight of this unit at a mean
specific impulse of 167 sec and a chamber pressure of 16 atm is given in
Table IV. This shows the total impulse/boost weight ratio to be 94 which
is similar to that obtained with the best scheme (No.6) for the smaller
unit.

There appears to be no reason why an increase in chamber pressure
and specific impulse should not give an improvement in performance
comparable to that obtained on the 43,000 lb-sec unit. This means that
the size of liquid boost units (within the limits considered) has very
little effect on their relative efficiencies. A liquid boost unit of
150,000 lb-sec impulse would take at least 3 years to develop.

5 Performance estimates of solid boost

The efficiency of a boost unit is best expressed in terms of the
total impulse per unit weight. In the case of the solid propellant,

where multiple motors are generally used, the weight can be either that of one motor only, or that of the complete boost unit including supporting structure. In the following paragraphs both these weights are necessarily used, the efficiency being expressed as either total impulse/motor weight or total impulse/boost weight.

Solid boost units at present in use utilize either a colloidal or a plastic propellant. Colloidal propellants have been extensively used and there is considerable experience of them available. They have a fairly high specific impulse, varying from 185 - 210 sec, but this is partially offset by the necessity for containing the propellant in a large steel tube. The use of light alloy tubing is under development but there are considerable difficulties to be overcome before it can be regarded as satisfactory.

Plastic propellants are a comparatively recent development, and at the moment consist of two main types, one being based on sodium nitrate and the other on ammonium perchlorate. The former type, which is the one in most common use, gives a low specific impulse of the order of 150 - 155 sec, but because of the higher specific gravity and higher density of loading it is possible to obtain the same total impulse as with colloidal propellants. The ammonium perchlorate type is the most recent development and gives a specific impulse between 185 and 210 sec. It has however certain temperature limitations which, up to date have given it only a restricted application.

5.1 Solid boost of total impulse 43,000 lb-sec

Table V gives comparative data on colloidal and plastic propellants contained in 5 inch A.T.O. steel tube motors. Table VI shows some typical figures for 5 inch light alloy tube motors with sodium nitrate and ammonium perchlorate fillings. The sodium nitrate motor with a total impulse/motor weight ratio of 93 has been used until recently on R.T.V.1, but is now being replaced by the ammonium perchlorate motor with a total impulse/motor weight ratio of 114. Although this particular perchlorate gives only a moderate specific impulse (185 - 190 sec) it is fairly reliable and has now been recommended for Service use in the temperate tropical range of temperatures.

An example of a high performance perchlorate is given in an A.R.E. report[4] where a specific impulse of about 210 sec and total impulse/motor weight ratio of 130 is quoted for R.D.2209 contained in a 5 inch light alloy tube. This perchlorate, however, is still under development and is not yet sufficiently reliable to be passed for Service use.

To sum up therefore it appears that:-

(a) a 5 inch plastic propellant motor based on sodium nitrate, and giving a total impulse/motor weight ratio of 93 is available for use over a limited temperature range.

(b) a 5 inch plastic propellant motor based on ammonium perchlorate and giving a total impulse/motor weight ratio of 114 has been satisfactorily developed for a limited temperature range. The extent to which it will be possible to use it, however, depends mainly on the production of an adequate supply.

(c) There is a reasonable prospect in the near future of obtaining a 5 inch plastic propellant motor giving a total impulse/motor weight ratio of about 130. Although it is difficult to estimate how long this will

take, it is not unreasonable to assume that it will be of the same order as that required to produce a comparable liquid unit.

As the total impulse obtainable from these 5 inch motors is relatively low, it is necessary to use a cluster of such motors to obtain higher impulses. The R.T.V.1 for example uses 7 of these 5 inch motors mounted in tandem. To enable a comparison to be made with the liquid boost units the previously quoted total impulse/motor weight ratio figures of 93, 114 and 130 must be modified to include the weight of the structure necessary to carry the complete boost. If the weight of the R.T.V.1 boost is taken as representative of a "tandem" arrangement the weight of the supporting structure amounts to about 20% of the total boost weight, thus giving a total impulse/boost weight ratios of 75, 91 and 104 for total impulse/motor weight ratios of 93, 114 and 130 respectively.

5.2 Solid boost of total impulse 150,000 lb-sec

The use of 5 inch motors to give a total impulse of 150,000 lb-sec is out of the question mainly because of the physical difficulty of fitting the large number required and the serious loss in efficiency due to the large weight of the boost structure. At the present time there is no large motor available of either the cordite or plastic propellant type although such motors are under development. Details of three motors now being developed are given in Table VII. Of these the plastic propellant type in a light alloy tube seems the most suitable as it gives a higher total impulse than the cordite (35,000 lb-sec as against 20,000 lb-sec) and a higher total impulse/motor weight ratio (131 as against 114). Although it is not a true comparison it is interesting to note that these total impulse/motor weight ratios are similar to those quoted for the 5 inch motors in para 5.1.

To give a total impulse of 150,000 lb-sec, four or five of these large plastic propellant motors would be required. If a "wrap round" boost were employed the weight of the boost structure would be lighter than for a tandem boost and would amount to about 10% of the total boost weight and give a total impulse/boost weight ratio of 118.

If the cordite motor were used seven or eight of them would be required, and again if it is assumed that a "wrap round" boost with a structure weight of 10% of the total boost weight is chosen the total impulse/boost weight ratio is 102.

It is difficult, however, to estimate how long the development of these large motors will take, but it will probably be at least as long, if not longer, than that required for a comparable liquid unit.

6 Comparison of liquid and Solid Boost Units

Comparative figures are given below for the performance and availability of liquid and solid boosts.

Type of boost		Total Impulse / Weight of Boost	Time when available
43,000 lb-sec Unit	Solid	75-91	Immediately
	Solid	104	Future
	Liquid	93-104	Future
150,000 lb-sec Unit	Solid	102-118	Future
	Liquid	94-105	Future

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It does not appear, therefore, if a comparison is made purely on a performance basis, that the liquid boost has any advantage over the solid.

The use of a "wrap round" liquid boost, however, has an operational advantage over the solid boost in that it permits the use of one large combustion chamber mounted on the axis of the projectile and thus ensures a purely axial thrust; in addition the propellant tanks can be mounted towards the forward end of the projectile and thus counterbalance the weight of the combustion chamber so that the shift in the centre of gravity is reduced to a minimum. On the other hand a liquid boost is much more complex than a solid boost which is very similar in structure and easy to handle.

There is one other factor, however, which may outweigh any operational advantages or disadvantages of either unit and that is the question of propellant manufacturing capacity. Whereas the supply of nitric acid and kerosene offers no great difficulty, the supply of high performance plastic propellants based on ammonium perchlorate is very limited[5]. Unless, therefore, the manufacture of perchlorate is stepped up to meet requirements, the development of a liquid boost unit might well be justified.

7   Conclusions

It should be possible to develop liquid boost units of total impulse 43,000 lb-sec and 150,000 lb-sec and values of total impulse/boost weight between about 93 and 105 lb-sec/lb.

This performance is slightly better than that given by existing solid boosts but the development of improved solid boosts is promising and on these grounds there seems little justification for the development of a liquid boost.

The liquid boost has the advantage of greater flexibility in installation as the combustion chamber can be fitted at the rear of the vehicle and thus ensures a purely axial thrust; at the same time the propellant tanks can be mounted at any suitable point around the body of the vehicle and so minimize the shift in the centre of gravity.

The manufacture of high performance plastic propellants in this country is at present on only a very small scale. If greater manufacturing capacity is not provided in the near future the development of a liquid boost unit might be justified on these grounds alone in view of the availability of nitric acid and kerosene.

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2	L.W.J. Newman	A small calibre rocket employing liquid fuel C.E.A.D. Note for Liquid Propellant Panel.
3	J.H. Crook, K.D. Errington and R.J. Rosser	The design and development of assisted take-off rocket motors A.R.E. Report No. 33/47, November, 1947.
4	J.H. Crook	Propellants, Plastic; Use with light alloy rocket motor. A.R.E. Report No.21/48, August, 1948.
5	C.G. Lawson	Solid rocket propellants. An appreciation of the present position in U.K. E.R.D.E. Tech. Memorandum No.12/M/48, December, 1948.

Attached:- Appendices I and II
Tables I - VII
Drgs. R.P.266 - 268

Advance Distribution:-

P/DSR (A)   Director, RAE
ADSR (Gen)   DDRAE(W)
D. Eng. RD   Supersonics Div.
Eng.RD.6   Guided Weapons
GW3 (Cdr. Ashworth)   (6)   Naval Aircraft
ADGW (R&D)   Chemistry Dept.
DGTD(A)   Armament Dept.
ERDE, Waltham Abbey   (6)   Library
TPA/TIB   (180)

APPENDIX I

Design Data for Liquid Boost Unit
of Total Impulse 43,000 lb-sec

1   Requirements

Total impulse 43,000 lb-sec
Thrust $5\frac{1}{2}$ tons (12,300 lb)
Duration $3\frac{1}{2}$ sec.

2   Specific impulse and weight of propellant

2.1 Combustion chamber pressure 16 atm

It is assumed that 90% of a theoretical specific impulse of 220
sec may be obtained i.e. the practical figure for the specific impulse
is 198 sec.

If an additional propellant consumption of (a) 7% or (b) 19% is
allowed for wastage at the start and end of combustion then for

(a)   the specific impulse is 185 sec
      the total consumption of propellant is 233 lb
and   the average rate of flow of propellant is 66.5 lb/sec.

and for

(b)   the specific impulse is 167 sec
      the total consumption of propellant is 258 lb
and   the average rate of flow of propellant is 73.5 lb/sec.

2.2 Combustion chamber pressure 30 atm

It is assumed that 90% of a theoretical specific impulse of 234 sec
may be obtained, i.e. the practical figure for the specific impulse =
210 sec.

If an additional propellant consumption of 19% is allowed for
wastage at the start and end of combustion then the mean value of the
specific impulse becomes 177 sec, the total consumption of propellant
242 lb and the average flow rate of propellant 69.5 lb/sec.

The ratio of HNO_3/kerosene is 5 : 1 (by weight).

3   Combustion chamber

Chamber Pressure (atm)	16	16	30
Mean Specific Impulse (sec)	167	185	177
Characteristic Length (L* in inches)	50	50	50
Vol. of Chamber (cu.ft)	1.42	1.28	0.735
Diameter of Chamber (in.)	14.5	14.13	11.75
Diameter of throat (in.)	7.91	7.5	5.7

For Scheme 1 (Fig.1) the combustion chamber is cooled by nitric
acid whilst for Schemes 2 - 6 (Figs. 2 and 3) the chamber is an uncooled
metal shell with an inner lining of polygon or similar refractory material.

4   <u>Propellant tank pressures</u>

The propellant pressures are as follows:-

<u>For chamber pressure of 16 atmospheres</u>

Chamber pressure	16 atm
Pressure loss between tanks and chamber	<u>10 atm</u>
∴ Tank pressures =	<u>26 atm</u>

<u>For chamber pressure of 30 atmospheres</u>

Chamber pressure	30 atm
Pressure loss between tanks and chamber	<u>10 atm</u>
∴ Propellant tank pressures =	<u>40 atm</u>

5   <u>Materials</u>

Combustion chamber, burner head, gaseous pipe lines, release mechanism	Mild steel
Injection component parts	18/8 Stainless Steel
Tanks	99.8% Aluminium or mild steel
Liquid pipe lines	99.8% Aluminium

APPENDIX II

Design Data for Liquid Boost Unit
of Total Impulse 150,000 lb-sec

1 Requirements

Total Impulse	150,000 lb-sec
Duration	$3\frac{1}{2}$ sec
Thrust	19.2 tons (43,000 lb)

2 Specific impulse and weight of propellant

It is assumed that 90% of a theoretical specific impulse of 220 sec may be obtained i.e. the practical figure for the specific impulse is 198 sec.

If an additional propellant consumption of 19% is allowed for wastage at the start and end of combustion then the mean specific impulse becomes 167 sec, the total consumption of propellant 900 lb and the flow rate of propellant 257 lb/sec.

The ratio of HNO_3/kerosene is 5 : 1 (by weight)

3 Combustion chamber

Chamber pressure (atm)	16
Characteristic length (L^* in inches)	50
Vol. of chamber (cu.ft)	4.98
Diameter of chamber (in.)	22
Diameter of throat (in.)	14.8

The chamber is an uncooled metal shell with an inner lining of polygon or similar refractory material.

4 Propellant tank pressures

The propellant tank pressures are as follows:-

Chamber pressure	16 atm
Pressure loss between tanks and chamber	10 atm
∴ Tank pressures	26 atm

5 Materials

Combustion chamber, burner head, tanks, gaseous pipe lines, release mechanism	Mild Steel
Injection component parts	18/8 Stainless steel
Liquid pipe lines	99.8% Aluminium

TABLE I

Comparative Weights of Liquid Boosts of Total Impulse 43,000 lb-sec
(Mean S.I. 167 sec Chamber Pressure 16 atm)

Scheme	Layout	Weight (lb)							Wt of Propellant Boost Wt	Total Impulse Boost Wt
		Tank	G.C.	Valves Pipes, etc.	Boost Structure	Dry Wt.	Propellants	Total Boost		
1	Tandem	156	72	22	56	306	258	564	0.46	76
2	8 × 4" Tube	115	82	24	52	273	258	531	0.48	81
3	Cyl. Ring	120	82	24	52	278	258	536	0.48	80
4	Ellip ring	117	82	24	52	275	258	533	0.48	81
5	4 × 4" Tube (AL)	81	82	24	50	237	258	495	0.52	87
6	4 × 5" Tube (Steel)	55	82	24	46	207	258	465	0.55	93

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TABLE II

Comparative Weights of Liquid Boosts of Total Impulse 43,000 lb-sec
(Mean S.I. 185 sec Chamber Pressure 16 atm)

Scheme	Layout	Weight (lb)							Wt of Propellant / Boost Wt	Total Impulse / Boost Wt
		Tank	C.C.	Valves Pipes, etc.	Boost Structure	Dry Wt.	Propellants	Total Boost		
3	Cyl. ring	115	82	24	50	271	233	504	0.46	85
4	Ellip ring	110	82	24	49	265	233	498	0.47	86
5	4 × 4" Tubes (Al)	73	82	24	45	224	233	457	0.51	94
6	4 × 5" Tubes (Steel)	50	82	24	42	198	233	431	0.54	100

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TABLE III

Comparative Weights of Liquid Boosts. Scheme 6 (4 x 5" Steel Tubes)
Combustion Chamber Pressures of 16 & 30 atm)

Combustion Chamber Press (atm)	Mean Specific Impulse (sec)	Weights (lb)							Wt of Propellant / Boost Wt	Total Impulse / Boost Wt
		Tank	C.C.	Valves pipes, etc.	Boost Structure	Dry Wt	Propellants	Total Boost		
16	167	55	82	24	46	207	258	465	0.55	93
30	177	70	64	24	44	202	242	444	0.55	97

TABLE IV

Weight of Liquid Boost of Total Impulse 150,000 lb-sec
(Mean S.I. of 167 sec, Chamber Pressure 16 atm)

Scheme	Layout	Weight (lb)							Propellant Wt / Boost Wt	Total Impulse / Boost Wt
		Tank	C.C.	Valves Pipes, etc.	Boost Structure	Dry Wt	Propellants	Total Boost		
7	4 x 9" Tubes (Steel)	200	287	55	158	700	900	1600	0.56	94

TABLE V

Comparative Data on 5" Steel Tube A.T.O. Motors using Colloidal and
Plastic Propellants at 60°F

Propellant	Time of Burning (sec)	Mean Thrust (lb)	Total Impulse (lb-sec)	Specific Impulse (sec)	Working Press lb/sq.in.	Venturi Throat Diam. (in.)	Wt of Propellant Charge (lb)	Length of Propellant Charge (in.)	Density of Loading (%)	Total Wt of Motor (lb)	Wt of Propellant/Motor Wt	Total Impulse/Motor Wt
Colloidal (SU/K coated)	3.9	1210	4920	189	450	1.6	25.9	37.9	71.8	61.5	0.42	80
Plastic RD.2043 (Sodium Nitrate)	3.8	1200	5000	153	1000	1.1	32.8	38.3	81	71.0	0.46	70
Plastic RD.2201 (Ammonium Perchlorate)	4.0	1450	6000	185	750	1.3	32.3	38.3	81	70.5	0.46	85

TABLE VI

Data on 5" Light Alloy Tube Motor as used with R.T.V.1

Propellant	Time of Burning (sec)	Mean Thrust (lb)	Total Impulse (lb-sec)	Specific Impulse (sec)	Wt of Propellant Charge (lb)	Total Wt of Motor (lb)	Wt of Propellant/Motor Wt	Total Impulse/Motor Wt
Plastic (Sodium Nitrate)	3.7	1835	6800	148	46	73	0.63	93
Plastic (Ammonium Perchlorate)	3.8	2150	8200	190	44.5	72	0.52	114

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TABLE VII

Data on Large Diameter Cordite and Plastic Propellant Motors

Under Development

Propellant	Total Impulse (lb-sec)	Specific Impulse (sec)	Overall Diameter (in.)	Overall length of Cylinder (in.)	Wt of Propellant (lb)	Total Wt (lb)	Wt of Propellant / Motor Wt	Total Impulse / Motor Wt
Cordite (Steel tube)	20,000	200	7.5	98	105	175	0.60	114
Plastic (Steel tube)	35,000	205	9.1	72	170	278	0.61	126
Plastic (Light alloy) tube)	35,000	205	9.1	72	170	267	0.64	131

PRESSURISING
CHARGE.

KEROSENE.

NITRIC
ACID

ENLARGED VIEW OF BOOST.

BOOST FITTED TO TEST VEHICLE.

FIG.I LIQUID BOOST UNIT, SCHEME I.

SECTION THROUGH A-A FOR:-

SCHEME 5 (4 X 4" ALUM. TUBES.)
"   6 (4 X 5" STEEL   "   )
"   7 (4 X 9"   "   "   )

GENERAL ARRANGEMENT OF TANKS FOR
SCHEMES 2, 5, 6 AND 7.

A———A

SECTION THROUGH A-A FOR
SCHEME 2 - (8 X 4" TUBES.)

BOOST COMBUSTION CHAMBER
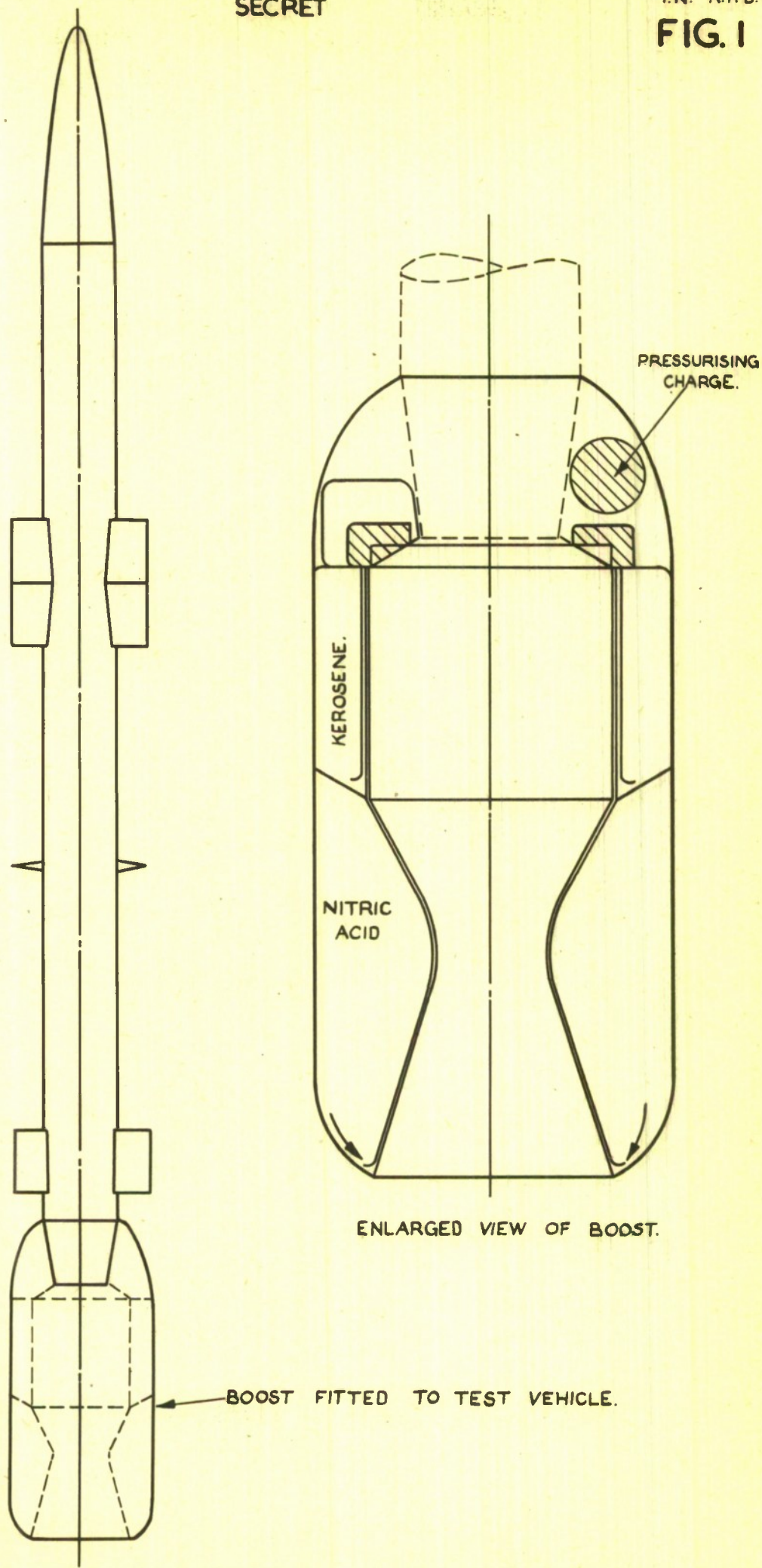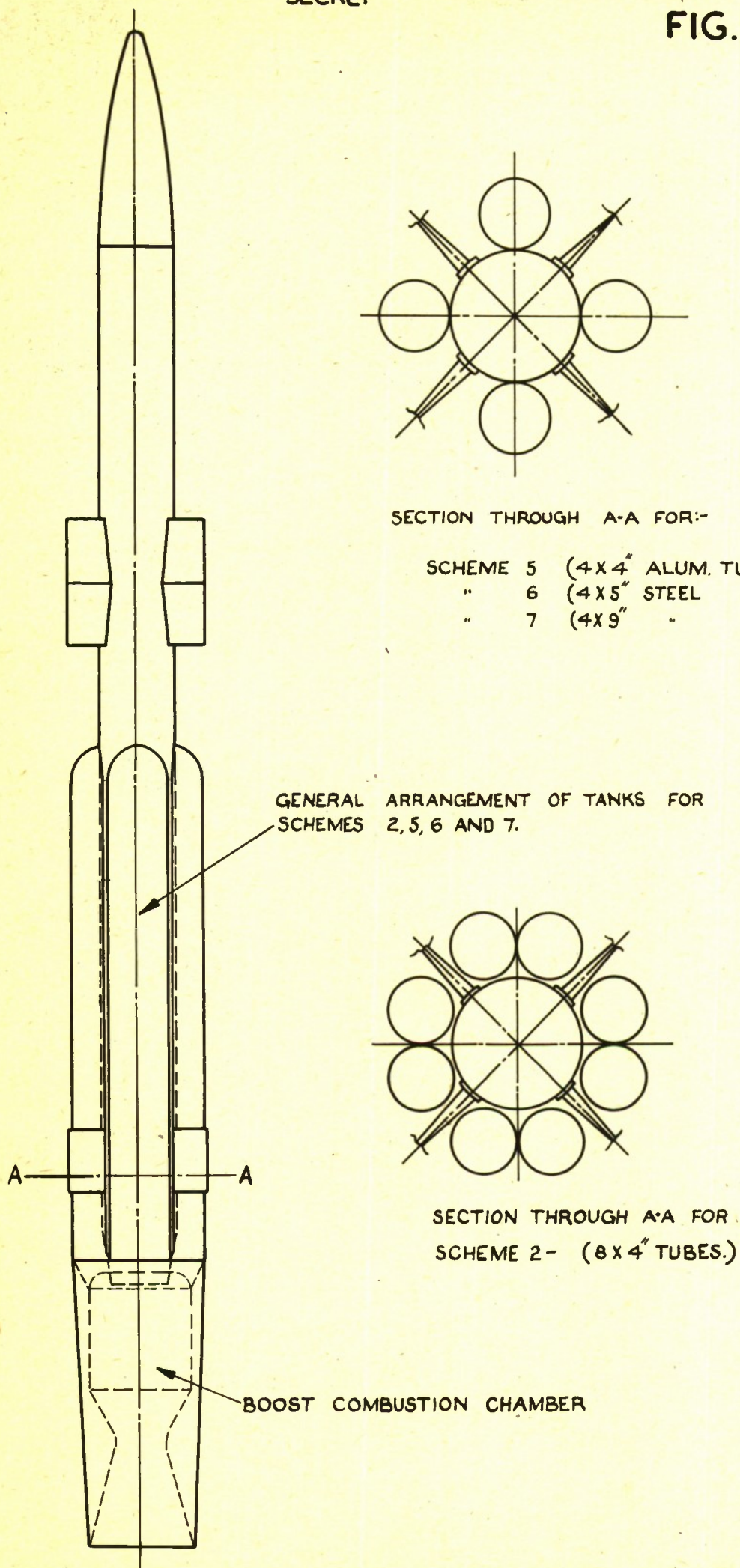
FIG. 2 LIQUID BOOST UNITS, SCHEMES 2, 5, 6 & 7.

BOOST TANK IN
FORM OF CYLINDRICAL
RING.

BOOST TANK IN
FORM OF ELLIPTICAL
RING.

BOOST COMBUSTION
CHAMBER.

SCHEME 3   SCHEME 4
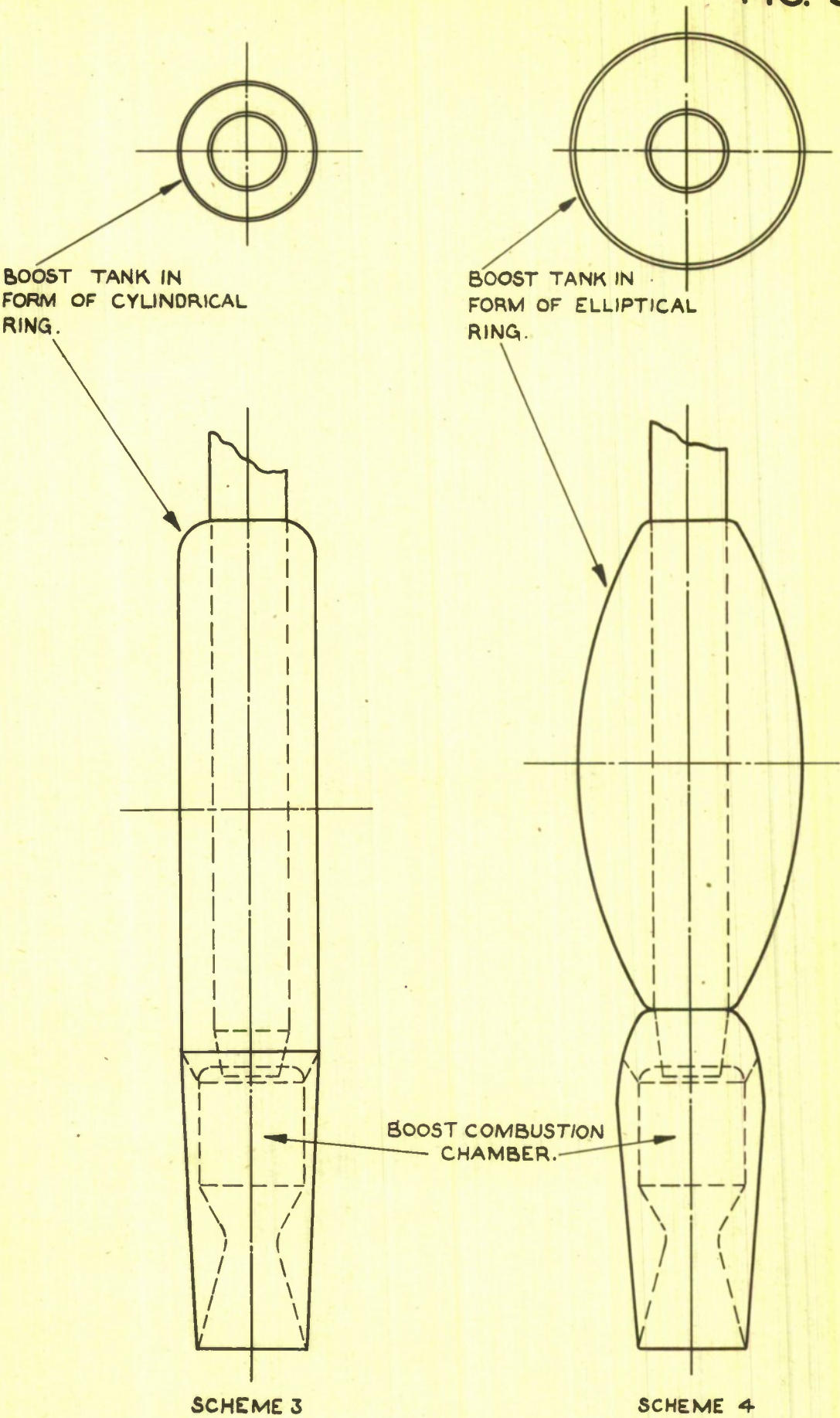
FIG.3 LIQUID BOOST UNITS, SCHEMES 3 & 4.

TITLE: A Comparison of Liquid and Solid Propellant Boost Rocket Motors - and
Appendixes I and II (Technical Note)

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ABSTRACT:

Development of liquid propellant rocket boost units of total impulse 43,000 and 150,000 lb-sec is
discussed, and their performance compared with that of the solid-propellant type. The conclusion is
reached that while liquid rocket boost units could be developed to give a better performance than solid
boosts known at present, the development of solid boosts giving as good, or better performance is
equally promising. The liquid boost has the advantage, however of greater flexibility in installation
in that the combustion chamber can be fitted at the rear of the vehicle and thus ensures a purely axial
thrust; at the same time the tanks can be mounted at any suitable point around the body of the vehicle
sot that the shift in the center of gravity is reduced to a minimum.

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